CLAIMS

We claim:

1. A processing container for electrochemically processing a microelectronic workpiece comprising:

a principal fluid flow chamber;

a plurality of concentric anodes disposed at different elevations in the principal fluid flow chamber so as to place the concentric anodes at different distances from a microelectronic workpiece under process; and

a controller configured to deliver through each of the concentric anodes a current that is (a) based upon a current delivered through the concentric anode to process an earlier-processed microelectronic workpiece and (b) selected to produce a more uniform processing of the workpiece under process than the processing of the earlier-processed microelectronic workpiece.

2. The processing container of claim 1 wherein the plurality of concentric anodes are arranged at increasing distances from the microelectronic workpiece from an outermost one of the plurality of concentric anodes to an innermost one of the plurality of concentric anodes.

3. The processing container of claim 2 wherein the principal fluid flow chamber is defined at an upper portion thereof by an angled wall, the angled wall supporting one or more of the plurality of concentric anodes.

4. The processing container of claim 1 wherein one or more of the plurality of concentric anodes is a virtual anode.

5. The processing container of claim 4 wherein the virtual anode comprises:

an anode chamber housing having a processing fluid inlet and a processing fluid outlet, the processing fluid outlet being disposed in close proximity to the microelectronic workpiece under process; and

at least one conductive anode element disposed in the anode chamber housing.

6. The processing container of claim 4 wherein the at least one conductive anode element is formed from an inert material.

7. The processing container of claim 1 and further comprising a plurality of nozzles disposed to provide a flow of the electrochemical processing fluid to the principal fluid flow chamber, the plurality of nozzles being arranged and directed to provide vertical and radial fluid flow components that combine to generate a substantially uniform normal flow component radially across the at least one surface of the workpiece.

8. The processing container of claim 1 wherein the principal fluid flow chamber is defined at an upper portion thereof by an angled wall, the angled wall supporting one or more of the plurality of concentric anodes.

9. The processing container of claim 1 wherein the principal fluid flow chamber further comprises an inlet disposed at a lower portion thereof that is configured to provide a Venturi effect that facilitates recirculation of processing fluid flow in a lower portion of the principal fluid flow chamber.

10. The processing container of claim 1, further comprising a current optimization subsystem for selecting the currents delivered through the concentric anodes by the controller.

11. The processing container of claim 10, further comprising a memory containing a Jacobian sensitivity matrix reflecting characteristics of the principal fluid flow chamber used by the current optimization subsystem in selecting the currents delivered through the concentric anodes by the controller.

12. The processing container of claim 1, further comprising a pump for circulating processing fluid within the principal flow chamber.

13. The processing container of claim 1 wherein the fluid flow chamber is adapted to contain an electrolyte solution for electroplating the microelectronic workpiece.

14. The processing container of claim 13 wherein the current delivered by the controller to each anode is selected to produce a more uniform layer of electroplated material on the microelectronic workpiece under process than was produced on the earlier-processed microelectronic workpiece.

15. A method for electroplating a material on a microelectronic workpiece comprising:

introducing at least one surface of the microelectronic workpiece into an electroplating bath;

providing a plurality of anodes in the electroplating bath, the plurality of anodes being spaced at different distances from the at least one surface of the microelectronic workpiece that is to be electroplated; and

for each of the plurality of anodes, inducing an electrical current between the anode and the at least one surface of the microelectronic workpiece, the induced electrical current being (a) based on an electrical current induced between the anode and a previously electroplated microelectronic workpiece and (b) selected to improve on an electroplating result achieved for the previously electroplated microelectronic workpiece.

16. A method of claim 15 wherein each of the plurality of anodes is provided with a fixed electrical current over a substantial portion of the electroplating process.

17. The method of claim 15 and further comprising the step of providing a substantially uniform normal flow of electroplating solution to the at least one surface of the microelectronic workpiece.

18. The method of claim 15 and further comprising the step of providing a substantially uniform normal flow of electroplating solution to the at least one surface of the microelectronic workpiece without an intermediate diffuser disposed between the plurality of anodes and the at least one surface of the microelectronic workpiece.

19. The method of claim 15 wherein each induced electrical current is selected to improve on a level of plating uniformly achieved for the previously electroplated microelectronic workpiece.

20. The method of claim 15 wherein each induced electrical current is selected to improve compliance of a plating profile achieved for the previously electroplated microelectronic workpiece with a target plating profile.

21. The method of step 15, further comprising selecting the induced electric currents.

22. The method of claim 21, further comprising performing a sensitivity analysis of the electroplating that is a basis for selecting the induced electric currents.

23. A reactor for electrochemically processing a microelectronic workpiece comprising:

a principal fluid flow chamber;

a plurality of electrodes disposed in the principal fluid flow chamber;

a workpiece holder positioned to hold at least one surface of the microelectronic workpiece in contact with an electrochemical processing fluid in the principal fluid flow chamber at least during electrochemical processing of the microelectronic workpiece;

one or more electrical contacts connected to electrically contact the at least one surface of the microelectronic workpiece;

an electrical power supply connected to the one or more electrical contacts and to the plurality of electrodes, at least two of the plurality of electrodes being independently connected to the electrical power supply to facilitate independent supply of power thereto;

a control system connected to the electrical power supply to control at least one electrical power parameter respectively associated with each of the independently connected electrodes, the control system setting the at least one electrical power parameter for a given one of the independently connected electrodes based on one or more user input parameters and a plurality of predetermined sensitivity values, the predetermined sensitivity values corresponding to process perturbations resulting from perturbations of the electrical power parameter for the given one of the independently connected electrodes.

24. A reactor as claimed in claim 23 wherein the at least one electrical parameter is electrical current.

25. A reactor as claimed in claim 23 wherein the sensitivity values are logically arranged within the control system as one or more Jacobian matrices.

26. A reactor as claimed in claim 23 wherein the at least one user input parameter comprises the thickness of a film that is to be electrochemically deposited on the at least one surface of the microelectronic workpiece.

27. A reactor as claimed in claim 23 wherein at least two of the independently connected electrodes are disposed at different effective distances from the surface of the microelectronic workpiece.

28. A reactor as claimed in claim 23 wherein the independently connected electrodes are arranged concentrically with respect to one another.

29. A reactor as claimed in claim 23 wherein the independently connected electrodes are disposed at the same effective distance from the at least one surface of the microelectronic workpiece.

30. A reactor as claimed in claim 29 wherein the independently connected electrodes are arranged concentrically with respect to one another.

31. A reactor as claimed in claim 27 wherein the independently connected electrodes are arranged concentrically with respect to one another.

32. A reactor as claimed in claim 31 wherein the independently connected electrodes are arranged at increasing distances from the at least one surface of the microelectronic workpiece from an outermost one of the plurality of concentric anodes to an innermost one of the independently connected electrodes.

33. A reactor as claimed in claim 23 wherein one or more of the independently connected electrodes is a virtual electrode.

34. A reactor as claimed in claim 33 wherein the virtual electrode comprises:

an electrode chamber housing having a processing fluid inlet and a processing fluid outlet, the processing fluid outlet being disposed in close proximity to the microelectronic workpiece under process;

at least one conductive electrode element disposed in the electrode chamber housing.

35. A processing container as claimed in claim 34 wherein the at least one conductive electrode element is formed from an inert material.

36. A processing container as claimed in claim 23 and further comprising a plurality of nozzles disposed to provide a flow of the electrochemical processing fluid to the principal fluid flow chamber, the plurality of nozzles being arranged and directed to provide vertical and radial fluid flow components that combine to generate a substantially uniform normal flow component radially across the at least one surface of the workpiece.

37. A reactor for immersion processing at least one surface of a microelectronic workpiece, the reactor comprising:

a reactor head including a workpiece support;

one or more electrical contacts disposed on the workpiece support and positioned thereon to make electrical contact with the microelectronic workpiece;

a processing container including a plurality of nozzles angularly disposed in a sidewall of a principal fluid flow chamber at a level within the principal fluid flow chamber below a surface of a bath of processing fluid normally contained therein during immersion processing;

a plurality of individually operable electrical conductors disposed in the principal fluid flow chamber and positioned for electrical contact with the processing fluid.

38. A reactor as claimed in claim 37 and further comprising an electrode disposed at a lower portion of the processing container to provide electrical contact between an electrical power supply and the processing fluid.

39. A reactor as claimed in claim 38 wherein the processing container is defined at an upper portion thereof by an angled wall, the processing container further comprising at least one further electrode in fixed positional alignment with the angled wall to provide electrical contact between an electrical power supply and the processing fluid.

40. A reactor as claimed in claim 37 and further comprising a motor connected to rotate the workpiece support and an associated microelectronic workpiece at least during processing of the at least one surface of the microelectronic workpiece.

41. A reactor for immersion processing of a microelectronic workpiece, the reactor comprising:

a processing container having a processing fluid inlet through which a processing fluid flows into the processing container, the processing container further having an upper rim forming a weir over which processing fluid flows to exit from processing container;

at least one helical flow chamber disposed exterior to the processing container to receive processing fluid exiting from the processing container over the weir.

42. A reactor as claimed in claim 41 wherein the helical flow chamber is disposed about and circumvents exterior sidewalls of the processing container.

43. A reactor as claimed in claim 42 wherein the processing container comprises one or more projections circumventing exterior sidewalls thereof that at least partially define the helical flow chamber.

44. A reactor as claimed in claim 43 wherein the reactor further comprises an outer container exterior to the processing container, interior sidewalls of the outer container cooperating with the one or more projections to define the helical flow chamber therebetween.

45. An apparatus for processing a microelectronic workpiece, comprising:

a plurality of workpiece processing stations;

a microelectronic workpiece robotic transfer;

at least one of the plurality of workpiece processing stations including a reactor having a processing container comprising

a principal fluid flow chamber;

a plurality of nozzles angularly disposed in one or more sidewalls of the principal fluid flow chamber at a level within the principal fluid flow chamber below a surface of a bath of processing fluid normally contained therein during immersion processing.

46. An apparatus as claimed in claim 45 wherein the plurality of nozzles are disposed with respect to one another to provide vertical and radial fluid flow components that combine to generate a substantially uniform normal flow component radially across the at least one surface of the workpiece.

47. An apparatus as claimed in claim 45 wherein the plurality of nozzles are arranged so that the substantially uniform normal flow component is slightly greater at a radial central portion as referenced to the workpiece thereby forming a meniscus that assists in preventing air entrapment as the workpiece is

brought into engagement with the surface of the processing fluid in the processing container.

48. An apparatus as claimed in claim 45 wherein the processing container further comprises a vented antechamber upstream of the plurality of nozzles.

49. An apparatus as claimed in claim 48 wherein the processing container further comprises a plenum disposed between the vented antechamber and the plurality of nozzles.

50. An apparatus as claimed in claim 48 wherein the vented antechamber comprises an inlet portion and an outlet portion, the inlet portion having a smaller cross-section compared to the outlet portion.

51. An apparatus as claimed in claim 47 wherein at least some of the plurality of nozzles are generally horizontal slots in the one or more sidewalls of the principal fluid flow chamber.

52. An apparatus as claimed in claim 45 wherein the principal fluid flow chamber further comprises a Venturi effect inlet.

53. An apparatus as claimed in claim 51 wherein the Venturi effect inlet generates a Venturi effect that facilitates recirculation of processing fluid flow in a lower portion of the principal fluid flow chamber.

54. A processing container for providing a flow of a processing fluid during immersion processing of at least one surface of a microelectronic workpiece, the processing container comprising:

a principal fluid flow chamber;

a plurality of nozzles angularly disposed in one or more sidewalls of the principal fluid flow chamber at a level within the principal fluid flow chamber below a surface of a bath of processing fluid contained therein during immersion processing.

55. A microelectronic workpiece processing container as claimed in claim 54 wherein the plurality of nozzles are disposed in the one or more sidewalls of the principal fluid flow chamber so as to form a the substantially uniform normal flow component radially across the surface of the workpiece in which the substantially uniform normal flow component is slightly greater at a radial central portion thereby forming a meniscus that assists in preventing air entrapment as the workpiece is brought into engagement with the surface of the processing fluid in the processing container.

56. A microelectronic workpiece processing container as claimed in claim 52 and further comprising an antechamber upstream of the plurality of nozzles, the antechamber being dimensioned to assist in the removal of gaseous components entrained in the processing fluid.

57. A microelectronic workpiece processing container as claimed in claim 56 and further comprising a plenum disposed between the antechamber and the plurality of nozzles.

58. A microelectronic workpiece processing container as claimed in claim 54 wherein the antechamber comprises an inlet and an outlet, the inlet having a smaller cross-section compared to the outlet.

59. A microelectronic workpiece processing container as claimed in claim 54 wherein at least some of the plurality of nozzles are generally horizontal

slots disposed through the one or more sidewalls of the principal fluid flow chamber.

60. A processing container as claimed in claim 54 wherein the principal fluid flow chamber comprises one or more contoured sidewalls at an upper portion thereof to inhibit fluid flow separation as the processing fluid flows toward an upper portion of the principal fluid flow chamber to contact the surface of the microelectronic workpiece.

61. A processing container as claimed in claim 54 wherein the principal fluid flow chamber is defined at an upper portion thereof by an angled wall.

62. A microelectronic workpiece processing container as claimed in claim 54 wherein the principal fluid flow chamber further comprises a Venturi effect inlet disposed at a lower portion thereof.

63. A microelectronic workpiece processing container as claimed in claim 62 wherein the Venturi effect inlet is configured to provide a Venturi effect that facilitates recirculation of processing fluid flow in a lower portion of the principal fluid flow chamber.